14

PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference	FOR FURTHER ACTION	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)
no ref		
International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/GB00/01103	23/03/2000	23/03/1999
International Patent Classification (IPC) or national classification and IPC G01L3/10		
Applicant FAST TECHNOLOGY GMBH et al.		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 9 sheets, including this cover sheet.

   ☒ This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of 10 sheets.

3. This report contains indications relating to the following items:

   - I ☒ Basis of the report
   - II ☐ Priority
   - III ☒ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   - IV ☐ Lack of unity of invention
   - V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations suporting such statement
   - VI ☐ Certain documents cited
   - VII ☒ Certain defects in the international application
   - VIII ☒ Certain observations on the international application

Date of submission of the demand	Date of completion of this report
23/10/2000	21.05.2001
Name and mailing address of the international preliminary examining authority: European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Authorized officer Helm, B Telephone No. +49 89 2399 2366

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No. PCT/GB00/01103

I. Basis of the report

1. With regard to the **elements** of the international application *(Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17))*:
Description, pages:

2-6,8-23	as originally filed			
1,7	as received on	26/04/2001	with letter of	24/04/2001

Claims, No.:

1-28	as received on	26/04/2001	with letter of	24/04/2001

Drawings, sheets:

1/6-4/6,6/6	as originally filed			
5/6	as received on	26/04/2001	with letter of	24/04/2001

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

   These elements were available or furnished to this Authority in the following language: , which is:

   - ☐ the language of a translation furnished for the purposes of the international search (under Rule 23.1(b)).
   - ☐ the language of publication of the international application (under Rule 48.3(b)).
   - ☐ the language of a translation furnished for the purposes of international preliminary examination (under Rule 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

   - ☐ contained in the international application in written form.
   - ☐ filed together with the international application in computer readable form.
   - ☐ furnished subsequently to this Authority in written form.
   - ☐ furnished subsequently to this Authority in computer readable form.
   - ☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
   - ☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. The amendments have resulted in the cancellation of:

   ☐ the description, pages:
   ☐ the claims, Nos.:
   ☐ the drawings, sheets:

5. ☒ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)):

   (Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.)
   see separate sheet

6. Additional observations, if necessary:

III. Non-establishment of opinion with regard to novelty, inventive step and industrial applicability

1. The questions whether the claimed invention appears to be novel, to involve an inventive step (to be non-obvious), or to be industrially applicable have not been examined in respect of:

   ☐ the entire international application.

   ☒ claims Nos. 2-28.

because:

   ☐ the said international application, or the said claims Nos. relate to the following subject matter which does not require an international preliminary examination (*specify*):

   ☒ the description, claims or drawings (*indicate particular elements below*) or said claims Nos. 2-28 are so unclear that no meaningful opinion could be formed (*specify*):
   see separate sheet

   ☐ the claims, or said claims Nos. are so inadequately supported by the description that no meaningful opinion could be formed.

   ☐ no international search report has been established for the said claims Nos. .

2. A meaningful international preliminary examination cannot be carried out due to the failure of the nucleotide and/or amino acid sequence listing to comply with the standard provided for in Annex C of the Administrative Instructions:

   ☐ the written form has not been furnished or does not comply with the standard.
   ☐ the computer readable form has not been furnished or does not comply with the standard.

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability;

citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	
	No:	Claims	1
Inventive step (IS)	Yes:	Claims	
	No:	Claims	1
Industrial applicability (IA)	Yes:	Claims	1
	No:	Claims	

2. Citations and explanations
see separate sheet

VII. Certain defects in the international application

The following defects in the form or contents of the international application have been noted:
see separate sheet

VIII. Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:
see separate sheet

Re Item I: Basis of the report

The amendments filed with the letter dated 24.04.2001 introduce subject-matter which extends beyond the content of the application as filed, contrary to Article 34(2)(b) and Rule 70(2)(c) PCT. The amendments concerned are the following:

Claim 1: "a bending moment acting about said axis due to an applied force"; "significant";

Claim 9: "a pole of a given/opposite polarity";

Claims 13 to 17, 19: "oriented to detect ... axis/annulus";

Claim 18: "located to be responsive ... about said axis";

Claim 20: "in a sense acting to eliminate ... with torque";

Claim 21: "a difference operation"; originally disclosed are only summing operations;

Claims 23 to 28: "transducer element is under a predetermined torque"; originally disclosed is that only portions of the shaft are subjected to a predetermined torque so that the amendments introduced into claims 23 to 28 are generalisations extending beyond the originally filed application documents.

Therefore, this report has been established as if these amendments had not been made or were not present in the respective claims.

Re Item III: Non-establishment of opinion

See Re Item VIII: Certain observations.

Re Item V: Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability

1. Prior Art

Reference is made to the following documents:

D1 = DE-A-34 37 379

D2 = IEEE Transactions on Magnetics, vol. MAG-18, no. 6, November 1982, K. Harada et al.: "A New Torque Transducer Using Stress Sensitive Amorphous Ribbons", pages 1767-1769

D3 = EP-A-0 321 662

D4 = US-A-4 697 460

2. Objections under Article 33(2) PCT (Novelty)

2.1. The general concept of
applying to a pretorqued torsion bar a ribbon, sleeve or in any other way a magnetoelastic material so that after this application, when the pretorque is released, the torsion bar is untwisted and the magnetoelastic material consequently is inversely twisted in the opposite direction in order to establish a magnetic field in the shaft which is deflected by a certain angle to the circumferential direction
is generally known in the art, see e.g. documents D1 (see e.g. abstract; page 15, line 3 to page 17, line 11; figures 2 to 4) and D2 (see e.g. abstract; page 1768, left-hand column, last paragraph to page 1768, right-hand column, Paragraph 3; figures 1, 4, 5).
According to both documents, a torque sensor is provided comprising a plurality of parallel ribbons of amorphous magnetostrictive material exhibiting unidirectional magnetoelastic anisotropy created by said pretorquing so that the anisotropy lies in a predetermined angel with respect to the circumferential direction.

2.2. Document D3 (see e.g. abstract; column 5, line 34 to column 9, line 58; figures 1 to 10) shows a similar arrangement, wherein said element is integral with the shaft and

has a plurality of circumferentially and longitudinally magnetised annular portions with opposing magnetisation.
Moreover, this document discloses a zero-point correction, wherein two torque-dependent signals are combined in order to provide a reference signal to control the gain of the sensor's signal output.

2.3. Therefore, claim 1 does not satisfy the criterion set forth in Article 33(2) PCT because the subject-matter of this claim is not new in respect of prior art as defined in the regulations (Rule 64(1)-(3) PCT).

Re Item VII: Certain defects

1. The features of the claims are not provided with reference signs placed in parentheses (Rule 6.2(b) PCT).

2. Contrary to the requirements of Rule 5.1(a)(ii) PCT, the relevant background art disclosed in the **documents D1 to D4** is not mentioned in the description, nor are these documents identified therein.

Re Item VIII: Certain observations

Objections under Article 6 PCT (Clarity/Conciseness)

1. The variation in wording between independent claims 1, 23, 24, 25 and 28 leaves the single general inventive concept linking those claims - as required by Rule 13 PCT - unclear. It is not appropriate to have more than a single independent claim in each category (apparatus/method) in this application.
In particular, these claims appear to relate effectively to the same subject-matter and to differ from each other only with regard to the definition of the subject-matter for

which protection is sought and in respect of the terminology used for the features of that subject-matter. The aforementioned claims therefore lack conciseness and are therefore not acceptable under Article 6 PCT.

The claims should have been recast to include only one independent claim in each category (apparatus/method) with dependent claims as appropriate (Rule 6.4(a)-(c) PCT).

Moreover, lack of clarity of the claims as a whole arises, since the plurality of independent claims makes it difficult, if not impossible, to determine the matter for which protection is sought, and places an undue burden on others seeking to establish the extent of the protection.

Hence, claims 1, 23, 24, 25 and 28 do not meet the requirements of Article 6 PCT.

2. Moreover, the dependent claims 2 to 22 are highly repetitive and appear to relate effectively to similar subject-matter and differ from each other only with regard to the definition of the subject-matter for which protection is sought and in respect of the terminology used for the features of that subject-matter. The aforementioned dependent claims therefore also lack conciseness and are therefore not acceptable under Article 6 PCT.

3. Claims 2 and 3 refer to a circumferentially magnetised ring. Obviously, a circumferential magnetisation results in a zero value of the magnetic field component at zero torque. However, this is in clear contradiction to the teaching of present claim 1, defining that the annulus provides a torque-dependent magnetic field component which has a significant **non-zero value** at zero torque.

Moreover, claims 1 to 11 and 23 to 28 contradict each other as some of them define a **longitudinal** direction of magnetisation or a **circumferential**, closed loop of magnetisation of the defined element on the one hand, others on the other hand stating that a predetermined pretorque has been applied to the element prior to and during of the establishing of the magnetisation so that a **helical** magnetisation is established when the pretorque has been released. This inconsistency renders these claims unclear (Article 6 PCT). It appears that the direction of magnetisation is neither longitudinal nor circumferential, but helical because of the applied pretorque.

4. In claims 1, 6, 7 and 8 a non-zero and a zero value for the magnetic field of the element is defined. However, even in case of a circumferential, closed loop of

magnetisation, the magnetic field is always present and never "zero". Probably, it is "zero" in a certain predefined direction. But this direction has not been defined in these claims.

5. The various regions and surfaces defined in claim 8 are so obscure and ambiguous that the technical interrelationship between the features defined in this claim is not apparent from the wording of the claim.

6. According to the above mentioned multitude of independent claims, inconsistencies and unclarities of the claims and the accordingly introduced doubts with respect to the scope of the claims, no meaningful opinion with respect to novelty and inventive step could be established with respect to claims 2 to 28.

TITLE: MAGNETISED TORQUE TRANSDUCER ELEMENTS

FIELD OF THE INVENTION

This invention is concerned with to a torque or force transducer based on a magnetised transducer element. The invention relates to a magnetised transducer element and to a method of forming such an element. The invention also relates to a transducer assembly and to a torque sensor system incorporating such an assembly.

The invention will be particularly described in relation to transducer elements which are of magnetoelastic material and which are circumferentially magnetised, that is are of an annular form, e.g. circular form, which is magnetised in a closed loop around the annulus. The prior art transducer elements of this type provide a zero output at zero applied torque which can present a problem in practical applications as will be explained below. However, the invention has wider application to other magnetic-based transducer elements which need not necessarily utilise the phenomenon of magnetoelasticity in generating a torque-dependent or force-dependent measurement flux. Examples of this more general class of elements are what will be called herein "longitudinal magnetisation" and "radially-spaced magnetisation".

Longitudinal magnetisation provides an annulus of magnetisation, on a torque-transmitting shaft for example, in which the magnetisation extends in an axial direction at the surface over a defined length and acts to provide a closed loop of magnetic flux within the shaft. This may be visualised as a torus of magnetic flux. This torus of flux is distorted under torque to provide a torque-dependent tangential component of magnetic field, that is

forming the transducer element as set forth in Claim 23, 24, 25 and 28.

Yet another aspect of the invention is a transducer assembly comprising at least one transducer element of the invention and a magnetic field sensor arrangement.

A further aspect of the invention lies in a torque sensor system including a signal processing means as set forth in Claim 20.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention and its practice will be further described with reference to Figs. 3 to 7 of the accompanying drawings in which:

Figs. 1a, 1b and 1c show examples of prior proposals for transducer elements magnetised to have a circumferential field,

Figs. 2a and 2b show an example of the emanated magnetic field for the transducer element of Fig. 1b subject to torques of opposite direction, i.e. clockwise (cw) and counter-clockwise (ccw);

Fig. 3 shows the circumferential magnetising of a transducer element under pre-torque and Fig. 3a shows the magnetising and pre-torque conditions as relating to a cross-section of the transducer element.

Fig. 4 shows a graph of magnetic field output (M_e) v. torque (T) for the circumferentially magnetised transducer element of Fig. 3 subject to a pre-torque.

Figs. 5a to 5d show response curves relating to different directions of pre-torquing and circumferential magnetisation;

Claims

1. A transducer element of a magnetic material for a torque or force sensor which comprises at least one annulus of magnetised material extending about an axis,

the at least one annulus being magnetised such that a closed loop of magnetic flux is established in the magnetic material,

the at least one annulus being responsive to a torque applied about said axis for a torque sensor or to a bending moment acting about said axis due to an applied force for a force sensor, as the case may be, to emanate a magnetic field component externally of said element that is a function of the applied torque or the applied force, as the case may be, characterised in that:

the magnetisation established in the at least one annulus provides a torque-dependent magnetic field component which has a significant non-zero value at zero torque or force and an essentially zero value at a non-zero torque or force, as the case may be.

2. A transducer element as claimed in Claim 1 in which the at least one annulus is in the form of an annular ring attachable to a shaft, and the annular ring is of a magnetoelastic material and is circumferentially magnetised.

3. A transducer element as claimed in Claim 1 in which the at least one annulus is of magnetoelastic material and is a circumferentially magnetised, integral portion of a shaft.

4. A transducer element as claimed in Claim 1 in which the at least one annulus is longitudinally magnetised in the direction of said axis.

5. A transducer element as claimed in Claim 4 in which the at least one annulus is an integral portion of a shaft.

6. A transducer element as claimed in Claim 2 or 3 comprising a first annulus of magnetised material and a second annulus of magnetised material, wherein said first annulus provides an essentially zero value of magnetic field component at a non-zero torque or force of a given polarity and said second annulus provides an essentially-zero value of magnetic field component at a non-zero torque or force of the opposite polarity.

7. A transducer element as claimed in claim 4 or 5 comprising a first annulus of magnetised material and a second annulus of magnetised material, wherein said first annulus provides an essentially zero value of magnetic field component at a non-zero torque or force of a given polarity and said second annulus provides an essentially-zero value of magnetic field component at a non-zero torque or force of the opposite polarity.

8 A transducer element as claimed in Claim 1 in which said element has a surface extending radially of said axis and comprising a first annulus of magnetisation extending to said surface and a second annulus of magnetisation extending to said surface outwardly of said first annulus, said first annulus and said second annulus

being magnetised to provide a magnetic field component therebetween which has a significant non-zero value at zero torque or force, as the case may be, and an essentially zero value at a non-zero torque or force, as the case may be.

9. A transducer element as claimed in Claim 8 in which said first annulus is magnetised in the direction of said axis with a pole of given polarity at said surface and in which said second annulus is magnetised in the direction of said axis with a pole of opposite polarity at said surface.

10. A transducer element as claimed in Claim 8 in which said first annulus and said second annulus are each magnetised to form a respective closed loop of circumferential magnetisation, and the respective closed loops of circumferential magnetisation are of opposite polarity.

11. A transducer element as claimed in Claim 5 or Claims 7 and 5 comprising a respective further annulus of magnetisation located radially inwardly of the at least one annulus of magnetisation and longitudinally magnetised in the axial direction with a polarity opposite thereto to form a closed loop of magnetic flux therewith.

12. A transducer assembly comprising a transducer element as claimed in Claim 1 and a magnetic sensor arrangement oriented to detect said magnetic field component.

13. A transducer assembly comprising a transducer element as claimed in Claim 2 or 3 and a respective magnetic sensor arrangement for the at least one magnetised annulus and oriented to detect a magnetic field component in the direction of said axis.

14. A transducer assembly comprising a transducer element as claimed in Claim 4 or 5 and a respective magnetic sensor arrangement for the at least one magnetised annulus and oriented to detect a magnetic field component in the circumferential (tangential) direction about said axis.

15. A transducer assembly comprising a transducer element as claimed in Claim 6 and first and second magnetic sensor arrangements for detecting a respective magnetic field component emanated by said first annulus and said second annulus, each of said first and second magnetic sensor arrangements being oriented to detect a magnetic field component in the direction of said axis.

16. A transducer assembly comprising a transducer element as claimed in Claim 7 and first and second magnetic sensor arrangements for detecting a respective magnetic field component emanated by said first annulus and said second annulus, each of said first and second magnetic sensor arrangements being oriented to detect a magnetic field component in the circumferential (tangential) direction about said axis.

17. A transducer assembly comprising a transducer element as claimed in Claim 8 and a magnetic sensor

arrangement oriented to detect said magnetic field component provided between said first annulus and said second annulus.

18. A transducer assembly comprising a transducer element as claimed in Claim 9 and a magnetic sensor arrangement located to be responsive to the magnetic field between said first annulus and second annulus and oriented to detect a magnetic field component in the circumferential (tangential) direction about said axis.

19. A transducer assembly comprising a transducer element as claimed in Claim 10 and a magnetic sensor arrangement oriented to detect a radially directed magnetic field component between said first annulus and said second annulus.

20. A torque sensor system comprising a transducer assembly as claimed in Claim 15 or 16 responsive to torque applied about said axis, wherein said first and second magnetic field sensor arrangements provide first and second torque-dependent signals respectively, and further including signal processing means which comprises a first channel responsive to at least one of the first and second torque-dependent signals, said first channel comprising an output means having a controllable gain for producing an output signal representing a measure of torque, and which also comprises a second channel comprising means for combining the first and second torque-dependent signals to provide a reference signal, said output means being responsive to said reference

signal to adjust its gain in a sense acting to eliminate changes in the response relating the first and second torque-dependent signals with torque.

21. A torque sensor system as claimed in Claim 20 in which the combining means is operable to effect a difference operation on said first and second torque-dependent signals.

22. A torque sensor system as claimed in Claim 21 in which the first channel is responsive to both of said first and second torque-dependent signals to effect a summing operation thereon.

23. A method of forming a transducer element which is as claimed in any one of Claims 1 to 5 in which the magnetisation of said at least one annulus is performed while the transducer element is under a predetermined torque about said axis.

24. A method of forming a transducer element which is as claimed in Claim 6 or 7 in which the magnetisation of the first annulus is performed while the transducer element is under a predetermined torque of one polarity about said axis, and the magnetisation of the second annulus is performed while the transducer element is under a predetermined torque of the opposite polarity about said axis.

25. A method of forming a transducer element as claimed in Claim 6 or 7 in which the respective magnetisations of the first annulus and the second annulus are performed to provide magnetisations of opposite polarity.

26. A method as claimed in Claim 24 in which the magnetisations of the first annulus and the second annulus are of the same polarity.

27. A method as claimed in Claim 25 in which the magnetisation of the first annulus is performed under a predetermined torque of opposite polarity to that applied in the magnetisation of the second annulus.

28. A method of forming a transducer element which is as claimed in Claim 8, 9 or 10 in which the magnetisation of said first annulus and said second annulus is performed while said element is under a predetermined torque about said axis.

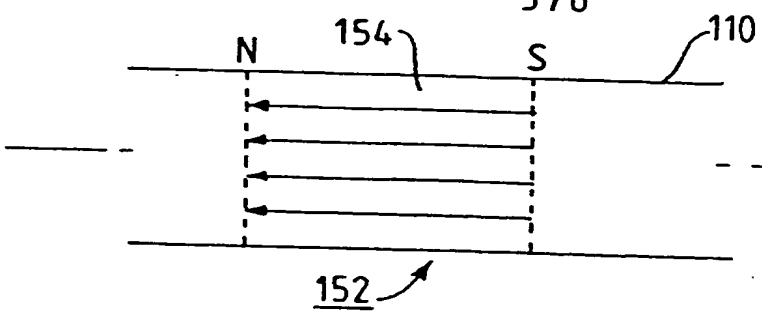

Fig.11a.

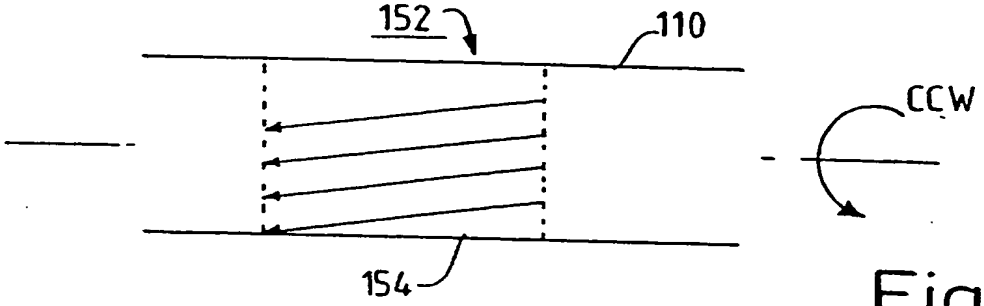

Fig.11b.

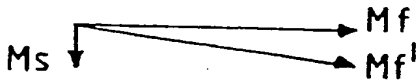

Fig.11c.

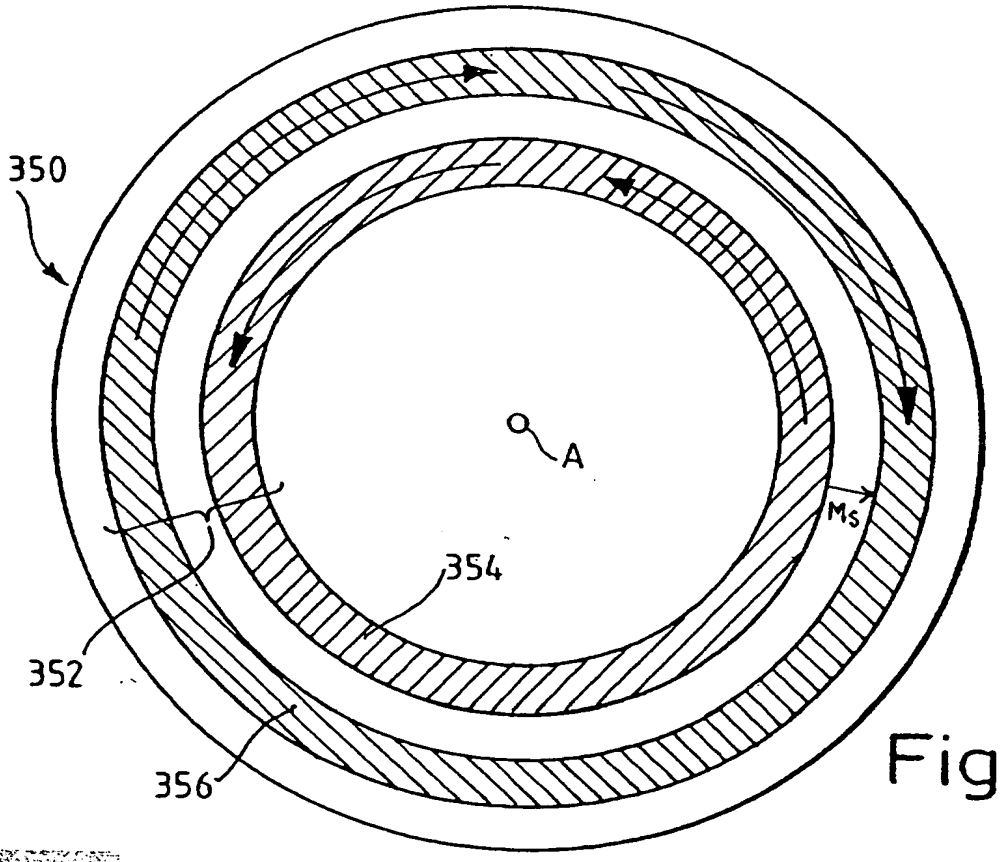

Fig.13.